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**Browy**

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(54) **PROJECTABLE DEVICE FOR USE WITH MIXED REALITY SYSTEM**

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This patent is subject to a terminal disclaimer.

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(60) Provisional application No. 62/688,222, filed on Jun. 21, 2018.

(51) **Int. Cl.**

| | |
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| ***G06T 11/00*** | (2006.01) |
| ***G02B 27/01*** | (2006.01) |
| ***G06K 9/00*** | (2022.01) |
| ***G06V 20/20*** | (2022.01) |

(52) **U.S. Cl.**

CPC ..... ***F42C 13/00*** (2013.01); ***G02B 27/0172*** (2013.01); ***G06T 11/00*** (2013.01); ***G06V 20/20*** (2022.01); *G02B 2027/014* (2013.01); *G02B 2027/0141* (2013.01)

(58) **Field of Classification Search**

CPC ..... F42C 13/00
USPC ..... 102/211, 214, 215
See application file for complete search history.

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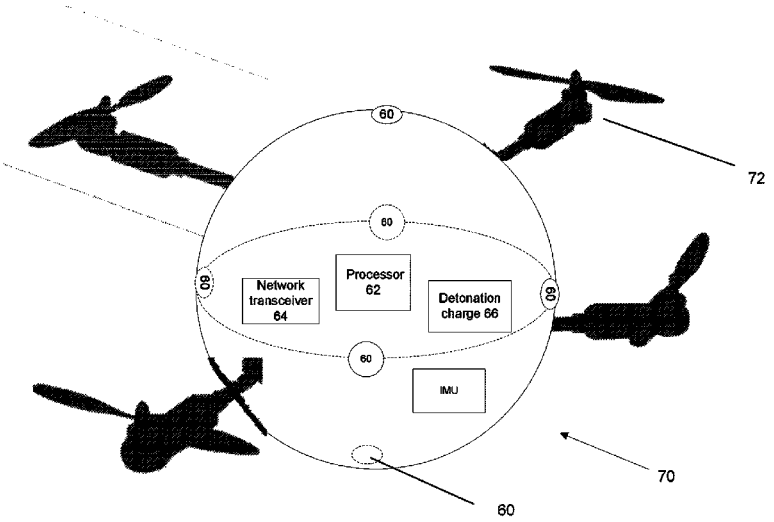
(57) **ABSTRACT**

A peripheral device that is used with a mixed reality system that is thrown by the user of the mixed reality system and captures scene and mapping data of the area the peripheral is thrown into. Upon capturing the scene and mapping data, the peripheral transmits the data (in some embodiments, including processed results of evaluation of the data) to the mixed reality system. The mixed reality system displays a visual representation of the scene and mapping data on a near eye display. In some embodiments, the visual representation appears in real space enabling an effect where the user of the mixed reality system can see through walls or other obstructions. In some embodiments, the peripheral is configured to detonate upon the satisfaction of a variable set of conditions.

**20 Claims, 7 Drawing Sheets**



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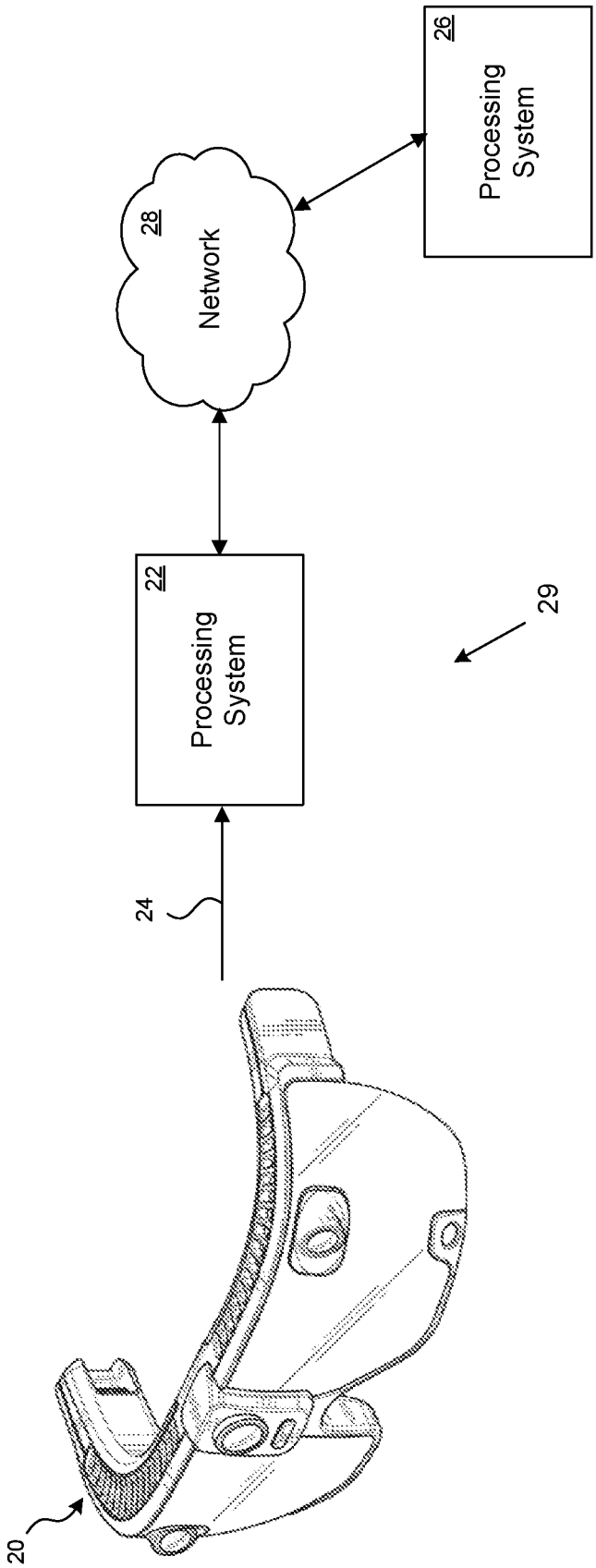
26
Processing System
28
Network
22
Processing System
29
24
20

*FIG. 1*

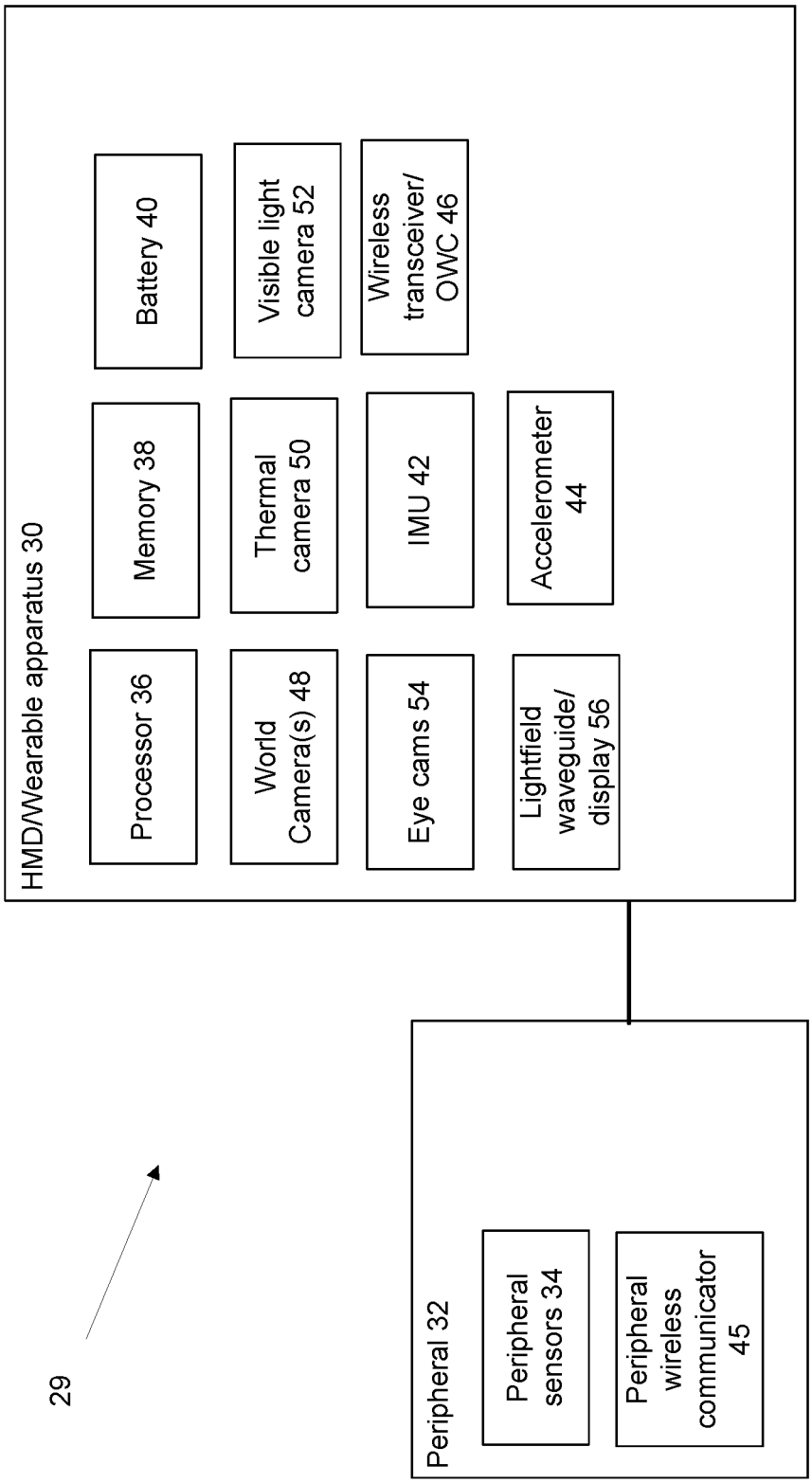
HMD/Wearable apparatus 30
Processor 36
Memory 38
Battery 40
World Camera(s) 48
Thermal camera 50
Visible light camera 52
Eye cams 54
IMU 42
Wireless transceiver/ OWC 46
Lightfield waveguide/ display 56
Accelerometer 44
Peripheral 32
Peripheral sensors 34
Peripheral wireless communicator 45
29

*FIG. 2*

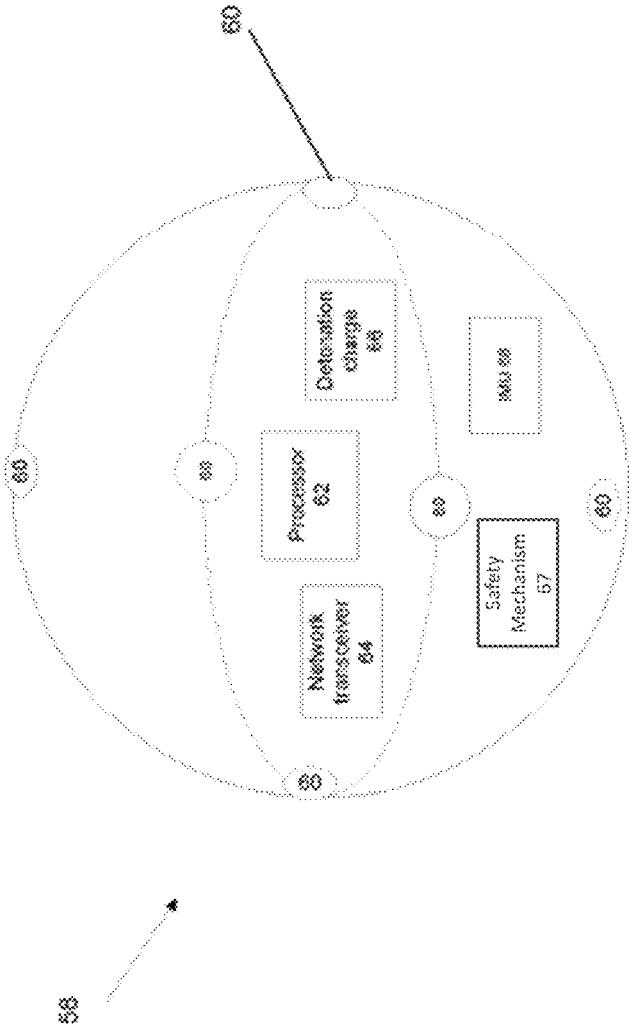
60
Detonation charge 66
Processor 62
Network transceiver 64
Safety Mechanism 67
68
58

FIG. 3

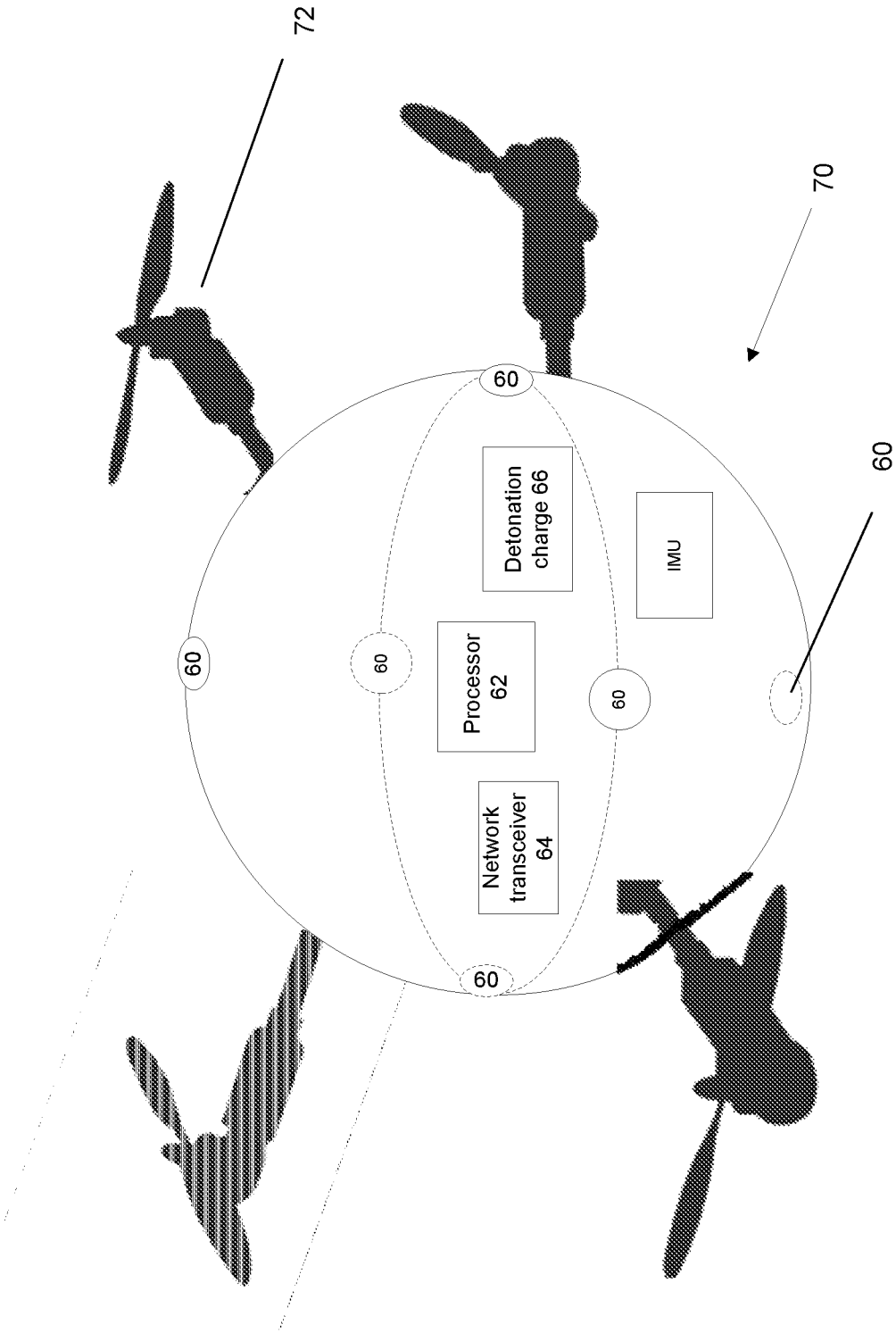
72
70
60
60
60
60
60
60
Detonation charge 66
IMU
Processor 62
Network transceiver 64

FIG. 4

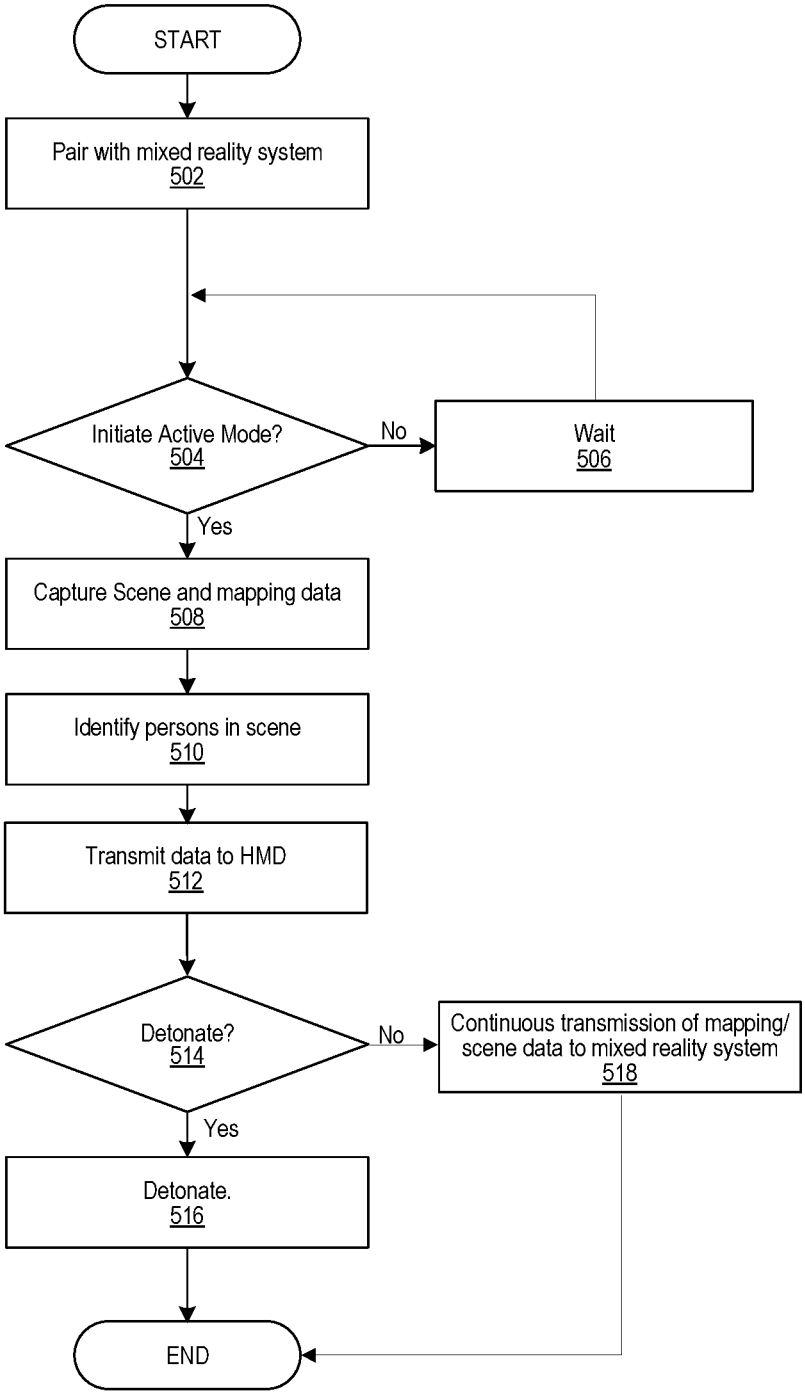
START
Pair with mixed reality system
502
Initiate Active Mode?
504
No
Wait
506
Yes
Capture Scene and mapping data
508
Identify persons in scene
510
Transmit data to HMD
512
Detonate?
514
No
Continuous transmission of mapping/ scene data to mixed reality system
518
Yes
Detonate.
516
END

*FIG. 5*

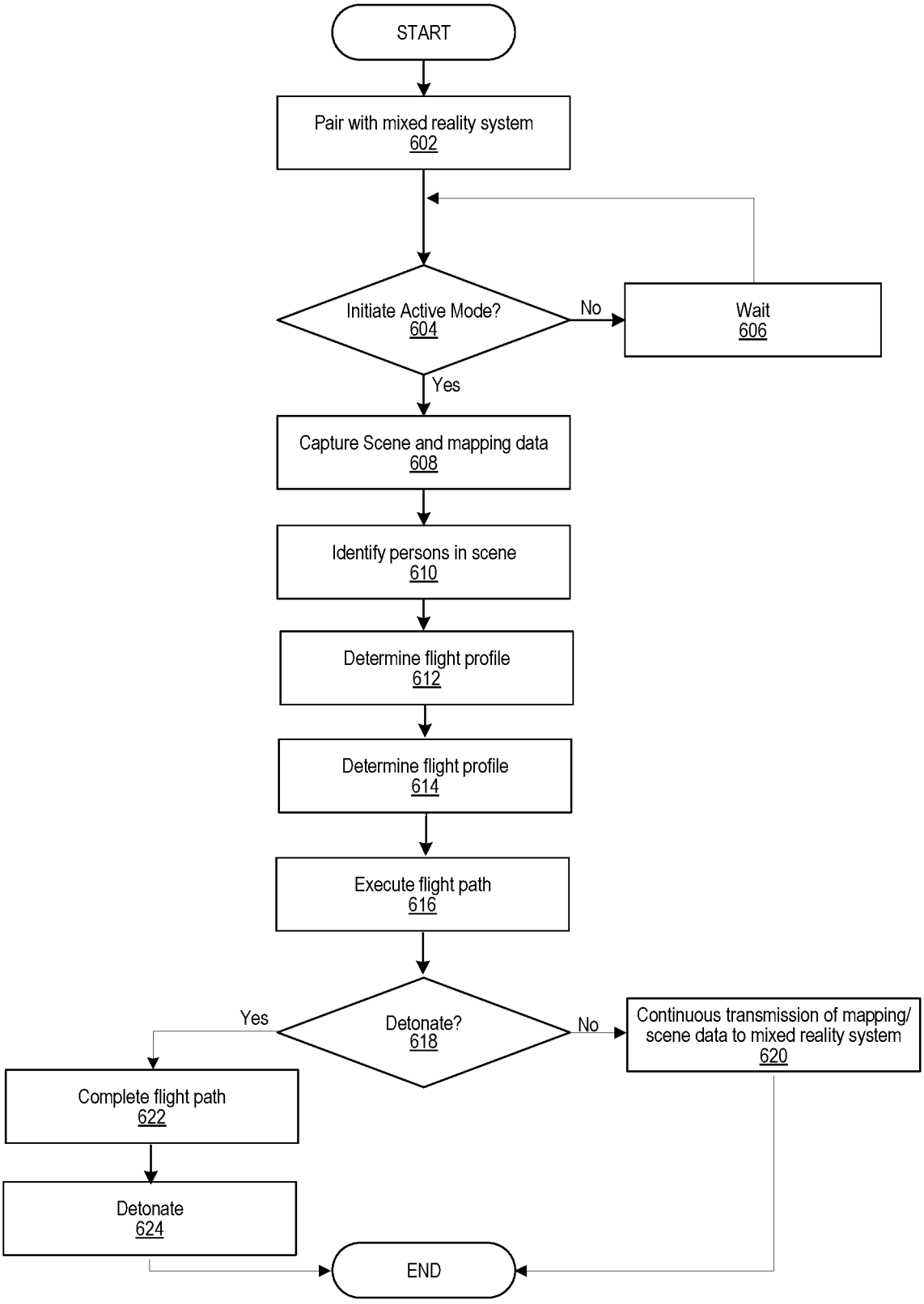
START
Pair with mixed reality system
602
Initiate Active Mode?
604
No
Wait
606
Yes
Capture Scene and mapping data
608
Identify persons in scene
610
Determine flight profile
612
Determine flight profile
614
Execute flight path
616
Detonate?
618
Yes
No
Continuous transmission of mapping/ scene data to mixed reality system
620
Complete flight path
622
Detonate
624
END

*FIG. 6*

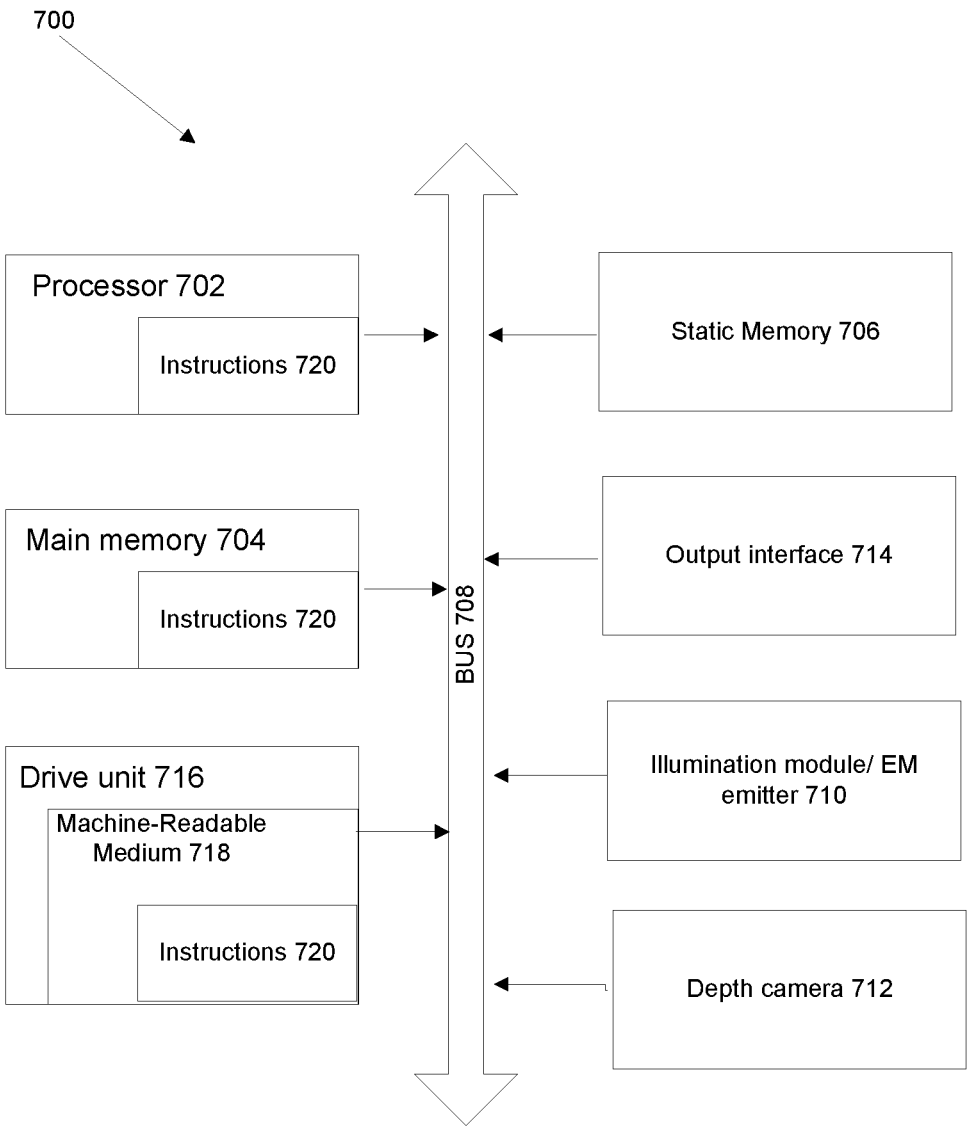
700
Processor 702
Instructions 720
Main memory 704
Instructions 720
Drive unit 716
Machine-Readable Medium 718
Instructions 720
BUS 708
Static Memory 706
Output interface 714
Illumination module/ EM emitter 710
Depth camera 712

*FIG. 7*

# PROJECTABLE DEVICE FOR USE WITH MIXED REALITY SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATION

The present disclosure is a continuation under 35 U.S.C. § 120 of U.S. patent application Ser. No. 16/445,510 that is titled "Device Performing Simultaneous Localization and Mapping", filed on Jun. 19, 2019, and further claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application Ser. No. 62/688,222, titled "Throwable Device Performing Simultaneous Localization and Mapping," which was filed on Jun. 21, 2018. The entire contents of the aforementioned priority documents are hereby explicitly incorporated by reference into the present disclosure for all purposes.

## INCORPORATION BY REFERENCE

U.S. patent application Ser. No. 15/600,545/U.S. Publication. No. 2017/0337470, filed on May 19, 2017 and entitled "METHOD AND SYSTEM FOR PERFORMING CONVOLUTIONAL IMAGE TRANSFORMATION ESTIMATION"; and U.S. patent application Ser. No. 15/717,747/U.S. Publication No. 2018/0096503, filed on Oct. 10, 2016 and entitled "PERIOCULAR TEST FOR MIXED REALITY CALIBRATION" are incorporated by reference for all purposes.

## TECHNICAL FIELD

This disclosure relates to mixed reality systems. More particularly, this disclosure relates to a mixed reality system that provides analysis on real world conditions through a GUI.

## BACKGROUND

Virtual Modern computing and display technologies have facilitated the development of systems for so called "virtual reality," "augmented reality," or "mixed reality" experiences, wherein digitally reproduced images or portions thereof are presented to a user in a manner wherein they seem to be, or may be perceived as, real. A virtual reality, or "VR," scenario typically involves presentation of digital or virtual image information without transparency to other actual real-world visual input; an augmented reality, or "AR," scenario typically involves presentation of digital or virtual image information as an augmentation to visualization of the actual world around the user; a mixed reality, or "MR," relates to merging real and virtual worlds to produce new environments where physical and virtual objects co-exist and interact in real time. An example process used to interpret scene data is with simultaneous localization and mapping (SLAM).

## SUMMARY

The present disclosure is generally directed to generating scene and/or mapping data for an environment, through use of a projectable device such as a throwable grenade and/or (e.g., piloted, autonomous, or semi-autonomous) drone. More specifically, the present disclosure is directed to generating scene and/or mapping data for an environment, through use of a projectable device that can be detonated after the scene and/or mapping data is generated, analyzed, and/or wirelessly communicated to at least one mixed reality system.

Embodiments of the present disclosure include a method performed by a projectable device, the method performing the following operations: establishing a wireless pairing between the projectable device and a mixed reality (MR) system, the wireless pairing enabling communication between the projectable device and the MR system; receiving scene and mapping data for an environment in proximity to the projectable device, the scene and mapping data captured by one or more cameras of the projectable device; transmitting the scene and mapping data to the MR system through the wireless pairing; and initiating a detonation of the projectable device using a detonation charge included in the projectable device.

Embodiments of the present disclosure can also optionally include one or more of the following aspects: the operations further include analyzing the scene and mapping data to generate information describing a presence of one or more people in proximity to the projectable device and an intent of the one or more people; the operations further include transmitting the information to the MR system through the wireless pairing; the detonation is initiated based at least partly on the intent; the operations further include receiving an indication to transition the projectable device from a low power mode to an active mode, wherein the scene and mapping data is captured by the one or more cameras when the projectable device is in the active mode; the indication is provided through manipulation of a switch or a pin on the projectable device; the indication is provided through an activation instruction that is transmitted to the projectable device from the MR system through the wireless pairing; the detonation is initiated responsive to a detonation instruction received from the MR system through the wireless pairing; the detonation is initiated responsive to motion data indicating that the projectable device has come to a stop following a period of motion, the motion data generated by at least one accelerometer in the projectable device; the projectable device is a throwable grenade; and/or the projectable device is a drone.

Embodiments of the present disclosure also include a projectable device (e.g., drone, grenade, etc.) configured to perform operations described herein. Embodiments of the present disclosure also include a system, including a projectable device, configured to perform operations described herein. Embodiments of the present disclosure also include memory (e.g., computer-readable storage media) that stores instructions that are executable perform operations described herein.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an example of an environment in which a mixed reality enabled head-mounted display device (hereinafter "HMD device") can be used.

FIG. **2** is a block diagram of hardware and software module interactions in an environment-oriented mixed reality system.

FIG. **3** is a block diagram of a SLAM-based grenade.

FIG. **4** is a block diagram of a SLAM-based drone

FIG. **5** is a flow chart illustrating operation of a SLAM grenade.

FIG. **6** is a flow chart illustrating operation of a SLAM drone.

FIG. **7** is a block schematic diagram of a system in the exemplary form of a computer system within which a set of

instructions for causing the system to perform any one of the foregoing methodologies and logical flows may be executed.

## DETAILED DESCRIPTION

In this description, references to "an embodiment," "one embodiment" or the like mean that the particular feature, function, structure or characteristic being described is included in at least one embodiment introduced here. Occurrences of such phrases in this specification do not necessarily all refer to the same embodiment. On the other hand, the embodiments referred to also are not necessarily mutually exclusive.

The figures and related text describe certain embodiments of an illumination module suitable for use in near-to-eye display (NED) systems, such as HMD devices. However, the disclosed embodiments are not limited to NED systems and have a variety of possible applications, including any active illumination systems (i.e., actively using light sources) such as used in active light projection systems or any active camera modules. Further included is a sensor suite of weapon system-connected sensors. All such applications, improvements, or modifications are considered within the scope of the concepts disclosed here.

The following description generally assumes that a "user" of a display device is a human. Note, however, that a user that is not human, such as a machine or an animal, can potentially use a display device of the disclosed embodiments. Hence, the term "user" can refer to any of those possibilities, except as may be otherwise stated or evident from the context. Further, the term "optical receptor" is used here as a general term to refer to a human eye, an animal eye, or a machine-implemented optical sensor designed to detect an image in a manner analogous to a human eye.

Virtual reality (VR) or augmented reality (AR) enabled HMD devices and other NED systems may include transparent display elements that enable users to see concurrently both the real world around them and AR content displayed by the HMD devices. An HMD device may include components such as light-emission elements (e.g., light emitting diodes (LEDs)), waveguides, various types of sensors, and processing electronics. HMD devices may further include one or more imager devices to generate images (e.g., stereo pair images for 3D vision) in accordance with the environment of a user wearing the HMD device, based on measurements and calculations determined from the components included in the HMD device.

A mixed reality system may also include a depth sensing system that resolves distances between an HMD device worn by a user and physical surfaces of objects in the user's immediate vicinity (e.g., walls, furniture, people and other objects). The depth sensing system may include a depth camera (e.g., measurements based on the phase of light, time of flight, parallax or stereo images, etc.) that is used to produce a 3D image of the user's nearby real-world environment. The captured image has pixel values corresponding to the distances between the HMD device and points of the real-world environment.

Object recognitions may be performed using a variety of computer vision techniques. For example, the wearable system can analyze the images acquired by the outward-facing imaging system to perform scene reconstruction, event detection, video tracking, object recognition (e.g., persons or documents), object pose estimation, facial recognition (e.g., from a person in the environment or an image on a document), learning, indexing, motion estimation, or image analysis (e.g., identifying indicia within documents such as photos, signatures, identification information, travel information, etc.), and so forth. One or more computer vision algorithms may be used to perform these tasks. Non-limiting examples of computer vision algorithms include: Scale-invariant feature transform (SIFT), speeded up robust features (SURF), oriented FAST and rotated BRIEF (ORB), binary robust invariant scalable keypoints (BRISK), fast retina keypoint (FREAK), Viola-Jones algorithm, Eigenfaces approach, Lucas-Kanade algorithm, Horn-Schunk algorithm, Mean-shift algorithm, visual simultaneous location and mapping (vSLAM) techniques, a sequential Bayesian estimator (e.g., Kalman filter, extended Kalman filter, etc.), bundle adjustment, Adaptive thresholding (and other thresholding techniques), Iterative Closest Point (ICP), Semi Global Matching (SGM), Semi Global Block Matching (SGBM), Feature Point Histograms, various machine learning algorithms (such as e.g., support vector machine, k-nearest neighbors algorithm, Naive Bayes, neural network (including convolutional or deep neural networks), or other supervised/unsupervised models, etc.), and so forth.

The object recognitions can additionally or alternatively be performed by a variety of machine learning algorithms. Once trained, the machine learning algorithm can be stored by the HMD. Some examples of machine learning algorithms can include supervised or non-supervised machine learning algorithms, including regression algorithms (such as, for example, Ordinary Least Squares Regression), instance-based algorithms (such as, for example, Learning Vector Quantization), decision tree algorithms (such as, for example, classification and regression trees), Bayesian algorithms (such as, for example, Naive Bayes), clustering algorithms (such as, for example, k-means clustering), association rule learning algorithms (such as, for example, apriori algorithms), artificial neural network algorithms (such as, for example, Perceptron), deep learning algorithms (such as, for example, Deep Boltzmann Machine, or deep neural network), dimensionality reduction algorithms (such as, for example, Principal Component Analysis), ensemble algorithms (such as, for example, Stacked Generalization), and/or other machine learning algorithms. In some embodiments, individual models can be customized for individual data sets. For example, the wearable device can generate or store a base model. The base model may be used as a starting point to generate additional models specific to a data type (e.g., a particular user in the telepresence session), a data set (e.g., a set of additional images obtained of the user in the telepresence session), conditional situations, or other variations. In some embodiments, the wearable HMD can be configured to utilize a plurality of techniques to generate models for analysis of the aggregated data. Other techniques may include using pre-defined thresholds or data values.

FIG. **1** schematically shows an example of an environment in which an HMD device **20** can be used, where such HMD device **20** can implement the techniques introduced here. In the illustrated example, the HMD device **20** is configured to communicate data to and from an external processing system **22** through a connection **24**, which can be a wired connection, a wireless connection, or a combination thereof. In other use cases, however, the HMD device **20** may operate as a standalone device. The connection **24** can be configured to carry any kind of data, such as image data (e.g., still images and/or full-motion video, including 2D and 3D images), audio, multimedia, voice, and/or any other type(s) of data. The processing system **22** may be, for example, a game console, personal computer, tablet computer, smartphone, or other type of processing device. The

connection **24** can be, for example, a universal serial bus (USB) connection, Wi-Fi connection, Bluetooth or Bluetooth Low Energy (BLE) connection, Ethernet connection, cable connection, digital subscriber line (DSL) connection, cellular connection (e.g., 3G, LTE/4G or 5G), or the like, or a combination thereof. Additionally, the processing system **22** may communicate with one or more other processing systems **16** via a network **18**, which may be or include, for example, a local area network (LAN), a wide area network (WAN), an intranet, a metropolitan area network (MAN), the global Internet, or combinations thereof. Above components contribute to the mixed reality system **29**.

FIG. **2** is a block diagram of hardware and software module interactions in an environment-oriented mixed reality system **29**. The system includes an HMD/wearable apparatus **30** as well as a peripheral **32** with mounted sensors **34**. The wearable apparatus **30** is processor-operated **36**, includes a local memory/digital storage **38**, and is powered by a battery **40**. The peripheral **32** may be an electronic device (e.g., a mobile phone), a mechanical device (e.g., a weapon system) or a totem object (e.g., a broom) that serves an additional or alterative purpose in virtual or augmented reality. Embodiments of the wearable apparatus **30** may include multiple physical components. Examples include an HMD and an additional unit such as a beltpack or backpack. The additional unit may include batteries and additional processing such as graphical processing and light field/scene rendering.

Other examples of worn units/peripherals **32** include biometric gloves. The biometric gloves include motion sensors that track finger movement to high degrees of precision. The wearable apparatus **30** further includes a suite of motion detection sensors such as inertial motion units (IMU) **42** and accelerometers **44**. IMUs **42** may be based on a number of hardware configurations such as gyroscopes to detect free space motion and orientation and magnetic fields to detect motion between local devices (e.g., an HMD and a belt pack, or peripheral). The motion detection sensors enable the mixed reality system **29** to monitor motion of the user both in space and in pose, positioning, and orientation. The peripheral **32** further includes a wireless communication system **45** in order to transmit sensor data to the worn apparatus **30**. In some embodiments, the mixed reality system **29** does not include a peripheral device **32**

The worn system further includes a means for wireless communication **46** with a network, and with other mixed reality systems **29**. The means for wireless communication includes network chips and associated antenna for Wi-Fi/IEEE 802.11 communication as well as Bluetooth, Zigbee, NFC, Bluetooth Low Energy, and cellular data protocols. The previously referenced protocols are often subject to interference and jamming behaviors (especially in combat zones). Further means for wireless communication include Optical wireless communication (OWC) such as an IR strobe and laser communication. IR strobes and laser communication are effective when in line of sight, and as scattered off local surfaces. IR systems are effective against jamming behavior because flooding an area with more IR light than the sun already does is sufficiently difficult to dissuade jamming. Jamming a laser communication system requires direct targeting jamming efforts against specific receivers.

In some embodiments, the IR strobe and laser communication may be used in conjunction. The IR strobe signals to nearby mixed reality systems **29** how and where to aim and transmit via laser communication. OWC communication uses both an emitter and a detector. The detector identifies a source of the IR strobe, and a laser emitter aims at the IR strobe. In order to reduce mechanical parts, the receiver for the laser transmitter may be a number of panels worn by a user. In some embodiments, the laser transmitter may transmit in a cone from the forward-facing perspective of a first user. Using a cone projection technique, the first user is able to transmit by looking at a second user. Reply communication can be performed by the IR strobe in a less directional manner. In use, the described scheme of IR strobe and laser communication enables communication between soldiers who may or may not be looking at one another at any given moment.

The HMD **30** includes a number of cameras including a scene mapping and depth sensing system ("world camera") **48**, a thermal camera **50**, a visible light camera **52**, and an eye tracking sensor **54**. The eye tracking sensor tracks the direction in which eyes are looking as well as identifies data about pupils (e.g., size, focus, rate of adjustment). The HMD **30** further includes a display screen **56** upon which digital images are displayed to the user. The display may comprise a waveguide or other lens system that enables viewing of the physical world in addition to the inclusion of digital elements. The display screen may also provide overlay images that affect contrast of the surrounding environment to improve vision in low light. The overlays are informed by the depth sensing system and the thermal camera **50**. While the device is "aware" of the surrounding scene using non-visible light, the scene may be re-rendered for the viewer using visible light for the user. The appearance is that of improved contrast for the wearer.

Both the eye tracking sensor **54** and the biometric glove are operable to determine a level of fatigue or alertness in a wearer. The biometric gloves collect finger movement data and combine those with known times of display of digital elements, and/or eye tracking data to monitor premotor neuron activity and response time to stimulus. For example, when the eye tracking sensor **54** identifies that the wearer looks at a first object, a timer is initiated. The timer is ended when finger movement data indicates that the wearer is reacting to observing the first object. Similarly, when a new object becomes displayed on the HMD **30**, the eye tracking sensor **54** may time how long it takes for the wearer to look at the new object, and how quickly their pupils focus on the new object. The biometric data enables the establishing of a metric for measuring fatigue of the wearer.

The peripheral includes sensors similar to that of the HMD **30**. The peripheral **32** includes motion sensors **34**, such as an IMU that tracks the peripheral motion relative to the worn apparatus and cameras for both visible and non-visible light. Where the peripheral is a weapon system, the peripheral sensors **34** include calibration relative to the weapon system loadout (e.g., ammunition type and count) and shape (e.g., positioning of barrel compared to positioning of the camera).

The mixed reality system **29** includes a plurality of software modules that enable processing of the numerous input streams and process data that is not perceptible to humans. Additionally, some embodiments may omit some of the aforementioned components and/or may include additional components not discussed above nor shown in FIG. **2**.

The mixed reality system **29** can be implemented in a squad/team/group configuration. In group embodiments, a number of mixed reality systems **29**, worn by a group of users, coordinate and share data therebetween. Scene capture and mapping, such as SLAM algorithms, from multiple mixed reality systems **29** can be used in an interconnected fashion to enable mapping of a broader area. Each mixed

reality system **29** includes world/depth cameras **48**. Through the operation of the world cameras on each mixed reality system **29**, a greater portion of a local area can be rendered and visually represented on each of the mixed reality systems **29**.

For example, a first user may be standing inside a first room and a second user may stand outside of the first room. The world camera of the first user captures the scene of the first room and transmits that scene to the mixed reality system **29** of the second user. The second user's mixed reality system **29** then displays the captured scene of the first room in real time and real space. The effect of the display of the first room to the second user is that the first room appears to the second user as if there were no walls to the first room obstructing the second user's view.

As applied across a group of mixed reality systems **29**, a local area may be mapped in real space and displayed "without walls." Placing the visual representation in real space is performed using the known distances between the SLAM grenade and the mixed reality system(s) **29** as well as the known distances from the SLAM grenade and the mixed reality system(s) **29** to other objects in the respective scene of each device.

As users move around, mapping data for a given area is no longer being captured in real time. Depending on the implementation and the use pattern, "stale" mapping data can become a liability. For example, if a user is shown that a room is empty and enters casually, an enemy may have entered the room after real-time data ceased. The enemy is then able to surprise the user. To avoid such a circumstance, mapping data that is not being captured in real time can fade or may be displayed differently (e.g., displayed in muted or greyed colors).

In some embodiments, a mixed reality system such as system **29** can communicate wirelessly with a device that can be projected (e.g., thrown, transported, piloted, or otherwise physically moved) into an environment that is remote from the mixed reality system and/or the user of the system. Such a projectable device can include cameras and/or other sensors that collect information regarding the environment into which the device is projected. The collected information can be analyzed on the device itself and/or communicated to the mixed reality system for further analysis. Such analysis can include SLAM performed for scene capture and mapping of the environment. In some examples, the projectable device is a thrown object such as a grenade. In other examples, the projectable device is a flown object such as a (e.g., remotely piloted, autonomous, or semi-autonomous) drone. The projectable device may be other suitable types of objects.

FIG. **3** is a block diagram of a SLAM-based grenade **58**. The SLAM grenade **58** is a throwable item including a number of depth cameras **60** oriented around the device, a processor **62**, a wireless transceiver **64** and a detonation charge **66**. The detonation charge **66** may be in any style grenades include (e.g., fragmentation, smoke, flash, etc.). In some embodiments, the exterior of the SLAM grenade **58** is "sticky." The stickiness is achieved by any of magnets, adhesive or adhesive jelly/putty. In embodiments including adhesive, an additional handle may be mounted to the grenade for handling. The SLAM grenade further comprises a safety mechanism **67** configured for implementing safety measures that prevent the detonation of the detonation charge **66**, as will be described in further detail below.

The SLAM grenade **58** is configured to capture ambient scene mapping data and transmit the mapping data to a corresponding HMD (or set of HMDs working together). The mapping data is translated into a visual representation of a room into which the SLAM grenade **58** is thrown. The visual representation is displayed on corresponding mixed reality systems **29** in real space using an augmented reality display. The room's visual representation enables the user to view the room the SLAM grenade **58** was thrown into as if no walls obscured the user's view of the room. The ability to "see" into a room before entering the room enables users in combat scenarios to evaluate danger of a room from the relative safety of an external position. As an alternative to real space presentation, in some embodiments, the room mapped by the SLAM grenade **58** may be represented in a "picture-in-a-picture" format. In an augmented reality circumstance, the wider "picture" is real world view via the user's eyes. The smaller "picture" is an augmented reality overlay.

Like the function of a group of mixed reality systems **29**, the SLAM grenade **58** acts as an additional mixed reality system **29** in the group to provide scene and mapping data to members of the group. When the scene/mapping data is no longer captured in real time, the visual representation of the room the SLAM grenade **58** is in can decay/fade/lose color over time.

In some embodiments, the SLAM grenade **58** is configured to recognize people as distinct from other objects in the room into which the SLAM grenade **58** is thrown. Person/human recognition can be performed using machine learning/deep learning neural nets/image recognition techniques. Data regarding persons in the room is processed by the mixed reality system **29** to identify the intent of those persons (e.g., by pose, clothing, and possessions including weapons). In some embodiments, the SLAM grenade **58** is configured to detonate where persons are detected in the room. Limitations on detonation are further customizable. For example, detonation may be prevented when a friendly user (as identified by wearing a mixed reality system, or other IFF tag) is within blast range of the SLAM grenade **58**. Another available limitation is to prevent detonation based on an evaluated intent of detected persons. For example, if the detected persons do not appear as enemy combatants, the grenade does not detonate. Evaluation for enemy status can be based on, for example, whether detected persons are carrying weapons.

The result of selective detonation is that the same SLAM grenade **58** may be used for multiple rooms. A user or group of users can work their way through a building by beginning every room breach by throwing the SLAM grenade **58** in first. The SLAM grenade **58** enables evaluation of each room before subjecting users to the dangers of a room, and neutralizes threats where they exist. Selective detonation further addresses the downsides of throwing a live grenade in every room. Grenades are not wasted on empty rooms, thus addressing a user's ability to carry a limited number of grenades. Further, the element of surprise is not blown on an empty room.

The SLAM grenade **58** operates using a battery. Thus, power conservation is an important aspect of operation. Combat hardware is built with reliability in mind. In order to conserve power in the field, the SLAM grenade **58** includes both an active mode and a lower power state. An example of a trigger that causes the SLAM grenade **58** to shift from one power state to another is an accelerometer threshold. The typical grenade toss has an identifiable velocity pattern that is distinct from hip mounted running. The velocity pattern can be detected by an IMU **68** within the

SLAM grenade **58**. In some embodiments, the power state is shifted based on the toggling of a physical switch, or removal of a pin.

An example of multiple power states that may be applied are similar to those employed in devices using machine-to-machine wireless protocol (e.g., Zigbee, Bluetooth, IEEE 802.15). The SLAM grenade **58** is configured to pair with a mixed reality system **29** and then remain in a low power mode until in use. When in active mode, the SLAM grenade **58** transmits scene and mapping data to the paired mixed reality system **29**.

FIG. **4** is a block diagram of a SLAM-based drone **70**. Like a SLAM grenade **58**, a SLAM drone **70** is thrown into a room prior to human entry. Where a SLAM grenade **58** would follow a parabolic flight path and experience the physics of wall bounces and rolling (and in some embodiments, wall sticking), the drone operates on a parabolic path transitioned to programmed flight. Drones can be programmed to begin flight operation upon being thrown.

SLAM drones **70** include similar circuitry as SLAM grenades **58**, and in some cases, a detonation charge **66**. The primary distinction between a SLAM grenade **58** and a SLAM drone **70** is that the SLAM drone **70** includes powered flight. Each SLAM drone **70** includes one or more powered devices **72** that impart motion to the SLAM drone **70** to traverse one or more corresponding flight paths. The SLAM drone **70** may include a number of flight profiles.

A first example of a flight profile is an observation profile. The observation profile is configured to fly into a high location in the room (determined based on scene and mapping data) and stay out of the way. In some embodiments, the observation profile is configured to make continuous erratic movements in order to present a less appealing target for enemy combatants.

A second example of a flight profile is a seek or distraction profile. The seek profile is configured to identify a person in the room and fly straight at them. The seek profile is intended to be used with a detonation charge **66** to provide single target effectiveness, or to act as a distracting element. An enemy combatant may have difficulty ignoring a drone flying straight at them. The charging SLAM drone **70** serves as an able distraction for users of the mixed reality system **29** who are attempting to breach the room.

A third example of a flight profile is a maximum damage profile. The maximum damage profile is configured to fly toward a central point between a number of detected persons in a room such that upon reaching that point, the detonation charge can have the maximum effectiveness.

Based on the chosen flight profile, the SLAM drone **70** may make use of variable flight speed. In some of the above flight profiles, an ideal speed is one where persons in the room the SLAM drone **70** flies into can clearly focus on the drone. In other flight profiles, the ideal speed for the SLAM drone **70** is as fast as possible in order to present a more difficult target.

FIG. **5** is a flow chart illustrating operation of a SLAM grenade. In step **502**, the SLAM grenade pairs with the mixed reality system. The pairing enables streamlined wireless communication therebetween. In some embodiments, the SLAM grenade pairs with multiple mixed reality systems and transmits data to a number of mixed reality systems at a time. In some embodiments, the mixed reality systems share the transmissions of the SLAM grenade in a peer-to-peer fashion.

In step **504**, the SLAM grenade determines whether to operate in active mode or low power mode. Power mode determinations are made based on whether the SLAM grenade is in use. Use is determined by user input (e.g., such as a switch, a pin, or a command received through the paired mixed reality system), or environmental input (e.g., detection of a predetermined velocity or acceleration pattern). Where the active power mode is not engaged, in step **506**, the SLAM grenade remains in a low power mode and waits for a trigger to initiate active mode.

Where the active power mode is engaged, in step **508**, the SLAM grenade uses the local cameras to capture scene and mapping data. In some embodiments, the SLAM grenade executes the SLAM (or similar) algorithm on the captured scene and mapping data. In step **510**, the SLAM grenade recognizes people from the scene and mapping data. The recognized people are further evaluated for intent. In some embodiments, computational cost of step **510** is pushed to the mixed reality system once the mixed reality system receives the relevant scene and mapping data. In step **512**, the SLAM grenade transmits scene and mapping data (along with results of any processing performed thereon) to the paired mixed reality system. The mixed reality system is able to make use of the data as appropriate. In some embodiments, the mixed reality system can use the scene data to display the scene in augmented reality in real space and real time. The scene appears as if there are no intervening walls that prevent the user of the mixed reality system from seeing into the room occupied by the SLAM grenade.

In step **514**, the SLAM grenade determines whether to detonate. The determination whether to detonate is based on any of user input and/or environmental input. User input may be direct commands received by the mixed reality system (e.g., voice, hand gesture, etc.) or based on input received on the SLAM grenade (e.g., a trigger and a timer). Environmental input is based on the onboard sensors of the SLAM grenade including an accelerometer and the world cameras. For example, if the accelerometer detects in velocity patterns matching thrown flight (e.g., parabolic motion), a detonation trigger may occur after the SLAM grenade comes to a complete stop.

Another example is that the SLAM grenade detonates based on the detection/recognition of persons present in the room with the SLAM grenade. Often, one does not want to use a grenade on an empty room, thus triggering detonation upon the detection of people saves grenades. Alternatively, in some applications (such as quarry or avalanche blasting), one only wants to detonate the grenade where no people are. In such circumstances, triggering detonation based on the lack of people saves lives.

Several safety measures can be applied to the determination whether to detonate. For example, when conditioned upon the detection of people, there may be a countdown timer of limiting when people detection begins. If the SLAM grenade is active upon the initiation of a throwing motion, the grenade detects the thrower (user). Detonating in the user's hand is an undesired result. As a further safety measure, the grenade may prevent the detonation trigger upon detection of a paired or friendly mixed reality system within the blast radius. Determination of blast radius is performed using the depth/world cameras to evaluate objects within the blast radius. The blast radius is predetermined based on the size of the detonation charge. Identification of the user by the world cameras can be performed using wireless signal strength (RSSI) combined with recognition of a person at the calculated distance using the depth camera.

Further evaluation of the blast radius is performed using machine learning to identify the strength/integrity of obstructions between the grenade and the user. For example, if a steel or concrete wall is between the user and the

grenade, the blast radius that may affect the user is significantly reduced. The evaluation of obstruction integrity can be performed by the SLAM grenade, the mixed reality system, or both in concert. For example, thickness of a wall can be determined based on known values of distance between the user and the grenade, the distance between the user and the wall, and the distance between the grenade and the wall (e.g., total distance=grenade to wall+user to wall+thickness of wall, solve for thickness of wall). The material of the wall is determined based on a computer vision evaluation. Wall or obstruction thickness and material composition enables the mixed reality system/SLAM grenade to evaluate the danger of detonation to the user or allies of the user.

The detonation evaluation may be performed continuously as circumstances around the SLAM grenade change. That is, a thrown grenade may initially not detonate until the user and the user's allies are at a safe distance. Once allied parties reach a safe distance, the grenade may detonate. Similarly, a thrown grenade may not initially detect non-allied persons. However, upon the subsequent detection of a non-allied person, the SLAM grenade may trigger detonation.

In step **516**, the SLAM grenade detonates. The detonation may be triggered internally within the grenade, based on a command from the mixed reality system, or by coordination between the grenade, the mixed reality system, and any other local friendly mixed reality systems. Where the determination is made to not detonate, in step **518**, the SLAM grenade continues to transmit scene and mapping data to the mixed reality system in real time. The transmission continues until the SLAM grenade is deactivated or placed on inactive/low power mode.

FIG. **6** is a flow chart illustrating operation of a SLAM drone. The SLAM drone operates similarly to the SLAM grenade with a number of notable variations. As an example of one of these variations, in step **612**, the SLAM drone determines a flight profile. The determination of the flight profile begins in response to the drone being thrown, or otherwise put into the air. The flight profile may be determined by predetermined programming, user controls, or contextual/environmental input.

An example of contextual or environmental input is whether the SLAM drone detects allied/non-allied persons and where those persons are relative to the SLAM drone. A second example of a contextual or environmental input is the size and shape of the room into which the SLAM drone is inserted. If a ceiling is higher than average, the drone may fly higher than average.

User input is useful to determine flight profiles where tactical decisions are made. For example, the role the SLAM drone is intended to take in a room breach affects the ideal flight behavior of the SLAM drone. Where the drone is intended to be a distraction, flying straight at non-allied persons detected is distracting. Where the drone is intended to gather information only, flying around in an erratic pattern with line of sight to most objects in the room is preferable. Where the drone is intended to do damage, flying to the center of a group of non-allied persons and detonating is preferred.

In step **616**, the drone executes the determined flight path. Notably, the execution of the flight path occurs after the initiation of scene capture and transmission. Though the steps of FIG. **6** can be performed in multiple orders, engaging scene detection as soon as the drone is active enables the most accurate scene detection (greater time spent observing leads to better observations).

In step **618**, the SLAM drone determines whether to detonate. Like the SLAM grenade, the SLAM drone evaluates many of the same conditions. However, the SLAM drone additionally bases the determination to detonate on the completion of a flight path condition (e.g., fly within range of a non-allied person). Upon reaching the determination to detonate, in step **622**, the drone completes the flight path, and then in step **624**, detonates.

An Example Machine Overview

The machine-implemented operations described above can be implemented at least partially by programmable circuitry programmed/configured by software and/or firmware, or entirely by special-purpose circuitry, or by a combination of such forms. Such special-purpose circuitry (if any) can be in the form of, for example, one or more application-specific integrated circuits (ASICs), programmable logic devices (PLDs), field-programmable gate arrays (FPGAs), system-on-a-chip systems (SOCs), etc.

Software or firmware to implement the embodiments introduced here may be stored on a machine-readable storage medium and may be executed by one or more general-purpose or special-purpose programmable microprocessors. A "machine-readable medium," as the term is used herein, includes any mechanism that can store information in a form accessible by a machine (a machine may be, for example, a computer, network device, cellular phone, personal digital assistant (PDA), manufacturing tool, any device with one or more processors, etc.). For example, a machine-accessible medium includes recordable/non-recordable media (e.g., read-only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; etc.), etc.

FIG. **7** is a block schematic diagram of a system in the illustrative form of a computer system **700** within which a set of instructions for causing the system to perform any one of the foregoing methodologies and logical flows may be executed.

The computer system **700** includes a processor **702**, a main memory **704** and a static memory **706**, which communicate with each other via a bus **708**. The computer system **700** further includes an illumination module **710** and a depth camera **712**. The computer system **700** also includes an output interface **714**, for example, a USB interface, a network interface, or electrical signal connections and/or contacts.

The disk drive unit **716** includes a machine-readable medium **718** on which is stored a set of executable instructions, i.e., software **720**, embodying any one, or all, of the methodologies described herein. The software **720** is also shown to reside, completely or at least partially, within the main memory **704** and/or within the processor **702**. The software **720** may further be transmitted or received over a network by means of a network interface device **714**.

In contrast to the system **700** discussed above, a different embodiment uses logic circuitry instead of computer-executed instructions to implement processing entities. Depending upon the particular requirements of the application in the areas of speed, expense, tooling costs, and the like, this logic may be implemented by constructing an application-specific integrated circuit (ASIC) having thousands of tiny integrated transistors. Such an ASIC may be implemented with CMOS (complementary metal oxide semiconductor), TTL (transistor-transistor logic), VLSI (very large systems integration), or another suitable construction. Other alternatives include a digital signal processing chip (DSP), discrete circuitry (such as resistors, capacitors, diodes, inductors, and transistors), field programmable

gate array (FPGA), programmable logic array (PLA), programmable logic device (PLD), and the like.

It is to be understood that embodiments may be used as or to support software programs or software modules executed upon some form of processing core (such as the CPU of a computer) or otherwise implemented or realized upon or within a system or computer-readable medium. A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine, e.g., a computer. For example, a machine-readable medium includes read-only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals, for example, carrier waves, infrared signals, digital signals, etc.; or any other type of media suitable for storing or transmitting information.

Further, it is to be understood that embodiments may include performing operations and using storage with cloud computing. For the purposes of discussion herein, cloud computing may mean executing algorithms on any network that is accessible by Internet-enabled or network-enabled devices, servers, or clients and that do not require complex hardware configurations, e.g., requiring cables and complex software configurations, e.g., requiring a consultant to install. For example, embodiments may provide one or more cloud computing solutions that enable users, e.g., users on the go, to access real-time video delivery on such Internet-enabled or other network-enabled devices, servers, or clients in accordance with embodiments herein. It further should be appreciated that one or more cloud computing embodiments include real-time video delivery using mobile devices, tablets, and the like, as such devices are becoming standard consumer devices.

From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

The invention claimed is:

**1**. A projectable device, comprising:

a detonation charge;

an image capturing device;

a processor operatively coupled to at least the detonation charge and the image capturing device; and

memory operatively coupled to the processor and storing thereupon a sequence of instructions which, when executed by the processor, cause the processor to perform a set of operations, the set of operations comprising:

determining an operating mode of the projectable device from a plurality of operating modes based at least in part upon an input, the plurality of operating modes comprising an active mode and an inactive mode;

transmitting at least some of image data captured by the image capturing device to a display system through a wireless connection between the projectable device and the display system; and

determining whether to prevent detonation or to initiate the detonation of the detonation charge based at least in part upon the operating mode and the at least some of the image data.

**2**. The projectable device of claim **1**, further comprising:

one or more flight profiles pertaining to one or more corresponding flight paths; and

one or more powered devices that impart motion to the projectable device to traverse at least one of the one or more corresponding flight paths.

**3**. The projectable device of claim **1**, wherein the input is provided by the mixed-reality system or an environmental input detected by the projectable device.

**4**. The projectable device of claim **1**, wherein, when it is determined that the operating mode of the projectable device is in the active mode, determining whether to prevent detonation or to initiate the detonation of the detonation charge comprises:

capturing the image data by the image capturing device after it is determined that the projectable device is in the active mode;

analyzing the at least some of the image data to generate an analysis result;

determining whether one or more head-mounted display (HMD) devices or a friendly person is present within a range threshold from the projectable device based at least in part upon the analysis result of the at least some of the image data to generate a determination result; and

preventing the detonation of the detonation charge based at least in part upon the determination result.

**5**. The projectable device of claim **1**, wherein, when it is determined that the operating mode of the projectable device is in the active mode, determining whether to prevent detonation or to initiate the detonation of the detonation charge comprises:

capturing the image data by the image capturing device after it is determined that the projectable device is in the active mode;

analyzing the at least some of the image data to generate an analysis result;

determining whether the analysis result includes information describing a target for detonation for the projectable device to generate a determination result; and

initiating the detonation of the projectable device based at least in part upon a threshold range pertaining to the detonation charge.

**6**. The projectable device of claim **1**, wherein, when it is determined that the operating mode of the projectable device is in the inactive mode, determining whether to prevent detonation or to initiate the detonation of the detonation charge comprises:

determining whether an indication to transition the projectable device from the inactive mode to the active mode is received; and

preventing the detonation of the detonation charge in absence of the indication.

**7**. The projectable device of claim **1**, wherein, when it is determined that the operating mode of the projectable device is in the inactive mode, determining whether to prevent detonation or to initiate the detonation of the detonation charge comprises:

determining whether an indication to transition the projectable device from the inactive mode to the active mode is received; and

receiving, at the projectable device, the indication to transition the projectable device from the inactive mode to the active mode.

**8**. The projectable device of claim **7**, wherein, when it is determined that the operating mode of the projectable device is in the active mode, and that the indication to transition is received at the projectable device, determining whether to prevent detonation or to initiate the detonation of the detonation charge comprises:

invoking the image capturing device to capture the image data after it is determined to transition the projectable device to the active mode;

analyzing the at least some of the image data to generate an analysis result;

determining whether the analysis result includes information describing a target for detonation for the projectable device to generate a determination result; and

initiating the detonation of the projectable device based at least in part upon a threshold range pertaining to the detonation charge.

**9**. The projectable device of claim **1**, wherein the display system comprises a head-mounted display (HMD).

**10**. A projectable device, comprising:

a detonation charge;

a safety mechanism that prevents the detonation of the detonation charge;

a motion sensor that captures at least one motion characteristics of the projectable device;

an image capturing device, wherein the projectable device is configured to perform a set of operations, the set of operations comprising:

determining an operating mode of the projectable device from a plurality of operating modes based at least in part upon an input or the safety mechanism, the plurality of operating modes comprising an active mode and an inactive mode;

transmitting at least some of image data captured by the image capturing device to a display system through a wireless connection between the projectable device and the display system; and

determining whether to prevent detonation or to initiate the detonation of the detonation charge based at least in part upon the operating mode and the at least some of the image data.

**11**. The projectable device of claim **10**, wherein the set of operations further comprises:

receiving an indication to transition the projectable device from a low power mode to an active mode, wherein

the image data is captured by the at least one image capturing device when the projectable device is in the active mode, and

the indication is provided through manipulation of the safety mechanism on the projectable device; and

initiating a detonation of the detonation charge.

**12**. The projectable device of claim **10**, wherein the display system comprises a head-mounted display (HMD).

**13**. A method, comprising:

determining an operating mode of a projectable device having a detonation charge from a plurality of operating modes based at least in part upon an input, the plurality of operating modes comprising an active mode and an inactive mode;

establishing a wireless connection between the projectable device and a display system, the wireless connection enabling communication between the projectable device and the display system;

transmitting at least some of image data captured by the image capturing device to the display system through the wireless connection between the projectable device and the display system; and

determining whether to prevent detonation or to initiate the detonation of the detonation charge based at least in part upon the operating mode and the at least some of the image data.

**14**. The method of claim **13**, wherein determining the operating mode of the projectable device wherein the input comprises a first input provided by the mixed-reality system or an environmental input detected by the projectable device.

**15**. The method of claim **13**, wherein determining whether to prevent the detonation or to initiate the detonation of the detonation charge comprises, when it is determined that the operating mode of the projectable device is in the active mode:

capturing the image data by the image capturing device after it is determined that the projectable device is in the active mode;

analyzing the at least some of the image data to generate an analysis result;

determining whether one or more head-mounted display (HMD) devices or a friendly person is present within a range threshold from the projectable device based at least in part upon the analysis result of the at least some of the image data to generate a determination result; and

preventing the detonation of the detonation charge based at least in part upon the determination result.

**16**. The method of claim **13**, wherein determining whether to prevent the detonation or to initiate the detonation of the detonation charge comprises, when it is determined that the operating mode of the projectable device is in the active mode:

capturing the image data by the image capturing device after it is determined that the projectable device is in the active mode;

analyzing the at least some of the image data to generate an analysis result;

determining whether the analysis result includes information describing a target for detonation for the projectable device to generate a determination result; and

initiating the detonation of the projectable device based at least in part upon a threshold range pertaining to the detonation charge.

**17**. The method of claim **13**, wherein determining whether to prevent the detonation or to initiate the detonation of the detonation charge comprises, when it is determined that the operating mode of the projectable device is in the inactive mode:

determining whether an indication to transition the projectable device from the inactive mode to the active mode is received; and

preventing the detonation of the detonation charge in absence of the indication; and

when it is determined that the operating mode of the projectable device is in the active modes,

wherein the image data includes stale data; and

displaying the stale data differently than non-stale data.

**18**. The method of claim **13**, wherein determining whether to prevent the detonation or to initiate the detonation of the detonation charge comprises, when it is determined that the operating mode of the projectable device is in the inactive mode:

determining whether an indication to transition the projectable device from the inactive mode to the active mode is received; and

receiving, at the projectable device, the indication to transition the projectable device from the inactive mode to the active mode.

**19**. The method of claim **18**, wherein determining whether to prevent the detonation or to initiate the detonation of the detonation charge comprises, when it is determined that the

operating mode of the projectable device is in the active mode, and that the indication to transition is received at the projectable device:

invoking the image capturing device to capture the image data after it is determined to transition the projectable device to the active mode;

analyzing the at least some of the image data to generate an analysis result;

determining whether the analysis result includes information describing a target for detonation for the projectable device to generate a determination result; and

initiating the detonation of the projectable device based at least in part upon a threshold range pertaining to the detonation charge.

**20**. The method of claim **13**, wherein the display system comprises a head-mounted display (HMD).

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